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Generic Service Water System Risk Based Inspection Guide

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ABSTRACT

This risk-based inspection guide is intended to supplement U.S. Nuclear Regulatory Commission (NRC) Temporary Instruction 2515/115, "Service Water System Operational Performance Inspection (SWSOPI)." The purpose of this guide is to assist NRC inspection team leaders and team members to prioritize inspection items and refine inspection plans so their inspections will address those elements that dominate the risk associated with the service water system. This generic document presents risk insights obtained from probabilistic risk assessments and historical operating experience. Because it is intended to assist inspections at all commercial U.S. power reactors (which have wide variations in service water system designs), some items may not be applicable to every plant. Where possible, the risk significance of the potential inspection items has been related to particular characteristics of plant design or environmental conditions so that inspectors can determine which items may be applicable to a specific plant.

FIN A6553: PRA Applications Program for Inspection of Nuclear Power Plants

EXECUTIVE SUMMARY

This guide is intended for use by Nuclear Regulatory Commission inspectors to assist them in performing reviews and inspections of service water systems (SWSs) at commercial nuclear power plants. Based on insights gained from probabilistic risk assessments (PRAs), in combination with experiences taken from recorded incidents, a list of inspection items was generated.

Plant specific PRAs indicate a wide variety of situations that can prove to be risk significant for a given plant. What can prove to be very risk significant for one plant may prove to be inconsequential for another. This guide makes an attempt to identify those items that have the potential to be risk significant for a broad number of plants. In general, the following items appear to be risk significant with regard to accident scenarios involving the SWS:

! Single failure vulnerabilities, common-cause failure mechanisms, or intake blockage mechanisms that could result in complete loss of the SWS

! Inadequacy of the as-built SWS to meet design flow requirements under realistic operating conditions

! Extended maintenance outages on individual SWS trains while at power

! Potential for flooding from service water system pipe breaks that disable all redundant trains of a safety related or essential support system

A review of historical experience was performed to determine what events have occurred and to ensure that any other significant scenarios not on the list above were included. This review produced the following results:

! Foreign objects and substances entering the SWS were found to be the most frequent source of failures

! System leaks were the second most numerous failure occurrence

! Corrosion and erosion were a frequent source of problems and were listed as a major source of leaks

! Incorrect alignment was also listed as a frequent failure occurrence

! Maintenance and unavailability issues were expressed as concerns for the SWS

! Cavitating flow caused numerous problems

! A number of design or installation problems were identified

In conclusion, the details of the above results were evaluated for the potential to produce or contribute to the risk significant items listed previously. As a result, a number of inspection items were produced. Because of the generic nature of this guide, an overall ranking by importance measures cannot be accomplished. What might be risk significant for one plant may be of little importance to another.

CONTENTS

ACRONYMS

AOV	air operated valve
BWR	boiling water reactor
CCW	condenser circulating water
EDG	emergency diesel generator
ESF	engineered safety feature
HX	heat exchanger
MIC	microbiologically-induced corrosion
NPSH	net-positive suction head
NRC	Nuclear Regulatory Commission
PRA	probabilistic risk assessment
PWR	pressurized water reactors
RHR	residual heat removal
SOV	solenoid operated valve
SWS	service water system

GENERIC SERVICE WATER SYSTEM RISK BASED INSPECTION GUIDE

1. RISK AND RELIABILITY INSIGHTS

Analysis of several probabilistic risk assessments (PRAs) indicate that the service water system (SWS) normally ranks from the middle to the top of system lists with respect to their importance for the prevention of core damage. This diversity in ranking occurs both because of plant design differences and differences in the quality of the SWS models developed for the PRAs. Often, the SWS ranks as the most important system for boiling water reactors (BWRs), while it frequently ranks in the middle of the system list for pressurized water reactors (PWRs). However, plant-specific PRAs may indicate the SWS as being the most risk significant system for either type of plant.

The risk significance of a SWS failure can come from two types of effects. One effect is the inability to cool equipment. The other is flooding of essential equipment by ruptures of SWS pipes.

Failure of the SWS to provide essential cooling for engineered safety feature (ESF) equipment results in the unavailability of the safety equipment. Total failure of the SWS impacts plant equipment in a manner similar to the loss of all ac power (i.e., station blackout). This is expected to result in core damage because of a reactor coolant pump seal loss-of-coolant accident in PWRs or because of suppression pool overheating causing loss of injection capability in BWRs. The most important potential causes for loss of all service water are usually unintended single failure vulnerabilities in the design, common-cause failure of like components in redundant SWS trains, and blockage of the intake structure.

Operational experience has also revealed that some older systems do not meet their original design flow requirements under some conditions. In some cases, various modes of operation for the system have been found to be incapable of supplying adequate flow or heat removal.

Unavailability of a single train of SWS usually results in the loss of the associated train of ESF equipment, leaving the plant vulnerable to single failures in the other available train of ESF equipment or its supporting equipment. PRAs have shown that maintenance outages of single SWS trains can contribute more to risk than does the potential for complete loss of the SWS because of random, common-cause failures.

The risk importance of SWS pipe ruptures goes beyond the immediate cooling capabilities of the system. The large volumes of water that can be moved by the SWS can quickly flood and incapacitate nearby equipment, particularly electrical equipment. Some of the individual plant examination PRAs that recently have been submitted show major risk contributions from SWS flooding scenarios that inundate motor control centers or switchgear rooms. Systems designed for gravity flow or susceptible to siphon flow are especially important to flooding scenarios. But pumped flow also has been shown to contribute to risk significant flooding scenarios. Generally, in order to be highly risk significant, the flooding potential must be able to incapacitate both trains of an ESF or an essential support system.

In summary, significant risk factors include:

! Single failure vulnerabilities, common-cause failure mechanisms, or intake blockage mechanisms that could result in loss of the SWS

! Inadequacy of the as-built SWS to meet design flow requirements under realistic operating conditions

! Extended maintenance outages on individual SWS trains while at power

! Potential for flooding to disable all redundant trains of a safety or essential support system

2. HISTORICAL EXPERIENCE

NUREG-1275[1] presents an assessment of the SWS concerning the types of failures and problems encountered in the nuclear industry. The significant failure events from reviewing the historical information are summarized below. These individual failure events are significant because they may be potential sources of common-cause failures, increased unavailability of redundant components, sources of single point system failures, or causes of the system to fail to meet design criteria.

Foreign objects and silt entering the SWS were found to be the most frequent source of failures. Components affected most frequently were heat exchangers (HXs), coolers, and pumps. In some cases, the objects caused high enough differential pressures that baffles collapsed. For example, Brunswick 2 had an accumulation of shells in a residual heat removal (RHR) HX that caused baffle plate displacement.

Foreign objects entering a pump may cause pump failure. Periodically, a wood object bypasses or gets through the traveling strainer or filter system on the SWS inlet. Several plants, including Turkey Point 3 and Quad Cities 1, have had pump failures because of wood entering the pump. Along with wooden objects, other items such as aquatic material (grass, eels, shells, etc.) can cause pump failure. The Surry 2 plant experienced two separate pump failures because of eels being caught in a pump impeller. Also, silting and fouling by aquatic material, sand, or dirt can cause fouling of pump impellers to the point where the pump is inoperable. A related problem occurred at Hatch 1. A standby RHR pump experienced silt buildup around the pump's suction bell, restricting flow to the pump during a test of operability.

To a lesser extent, valves, pipes, and strainers experienced jamming and plugging by foreign objects. For example, Surry 1 experienced a stuck open check valve because of SWS debris. *The risk importance from foreign objects consists of the circulation of objects throughout the SWS, potentially causing common-cause failures or degraded SWS flow*. A deluge of debris or biological material into the intake structure may reach several pumps on redundant SWS trains, possibly causing common-cause failure of the pumping system. Oyster Creek experienced failure of two SWS pumps because of grass clogging the pump-inlet screens. Also, Brunswick 2 lost both the A and B RHR HXs because of an ingress of oyster shells.

System leaks were the second most numerous failure occurrence. *Leaks can be risk significant because of wide-ranging damaging effects on safety related components or other safety systems*. The components that were predominately affected were HXs, coolers, or pipes. Also, system leaks were often coupled with corrosion or erosion. In fact, several plants (such as Salem 2, Zion 2, Millstone 2, and Kewaunee) have found erosion or corrosion problems after investigating system leaks. Additionally, a SWS leak at Robinson 2 caused degradation of the containment boundary. Degradation of containment during off-normal conditions (such as loss of SWS) can significantly increase risk. Also, potential flooding from failure of the rubber bellows used for expansion joints in the gravity flow design SWS at Surry has dominated core damage frequency in the Surry Individual Plant Examination.[2]

Corrosion or erosion generally causes either pipe plugging (from corrosion products flaking off) or pipe failure (from corrosion or erosion degrading pipe walls or pipe lining). The corrosion or erosion problems, including galvanic corrosion, could potentially plug redundant components, including valves or HXs. *Thus, risk significance from system leaks includes both the potential for large scale leaks (which may lead to complete loss of SWS) and corrosion/erosion problems (both blockage and equipment degradation potential) coupled with the system leaks*. Also, SWS leaks could impact other safety related systems. For example, the Salem 2 plant had a leak that allowed water to enter the emergency diesel generator (EDG) oil cooler, thereby disabling the EDG. At Palo Verde, microbiologically-induced corrosion (MIC) caused welds in the essential spray pond piping to leak.

Incorrect alignment was the third most common SWS failure occurrence and most frequently affected valves, HXs, and coolers. *Incorrect alignment of SWS components or trains is especially risk significant because of the potential for single point failure paths and, to a lesser extent, degraded flow and flow balance problems*. For instance, the Millstone 2 plant had both A and B HXs aligned to the same header. This event did not cause total loss of the SWS, but did cause a loss of SWS redundancy. But other misalignment events also have caused system failures. Brunswick 1 had a shut isolation valve (for the suction pressure switch) that caused the loss of two out of four SWS pumps. Also, at Zion 2, personnel caused flooding of the EDG fuel oil storage tank room. Severe flow imbalances resulting from incorrect alignment can have a potentially risk significant affect on critical equipment that is placed under accident loads.

Maintenance and unavailability issues are concerns for the SWS. *These types of issues are risk significant because of the increased exposure that exists for single failure vulnerabilities and personnel errors*. If one SWS train is unavailable, the plant is susceptible to single failures in the opposite train. Also, human errors during maintenance could be repeated for both trains of SWS. For instance, the Salem 1 plant had a redundant SWS train tagged out for maintenance when a short caused failure of the other train. The failure resulted in the complete loss of all service water for approximately one hour. At the Farley 2 plant, SWS valves to coolers were closed during maintenance and were not reopened after completion of maintenance. This demonstrates the importance of postmaintenance testing and verification of system restoration.

Cavitation may occur because the SWS is typically a low pressure system. *The risk significance from cavitation consists both of potential pump failure and cavitation-caused pipe or valve erosion and component fatigue failure*. For example, the Susquehanna 1 plant declared all SWS pumps inoperable after they were damaged by cavitation.

Design or installation problems have been found concerning the SWS. *The risk significance of this problem stems from the unanalyzed nature of the installed system*. For example, Millstone 2 had an improperly designed header cross-tie valve that stroked open upon restoration of instrument air. Also, numerous plants (San Onofre 1, Indian Point 3, North Anna 1, Calvert Cliffs, etc.) have had the potential for loss of SWS during a seismic event because of inadequate seismic SWS design. Also, some plants have revealed SWS single point failure paths. For example, Indian Point 3 had a single switch that controlled all service water pumps. Calvert Cliffs 2 had a failure of a nonsafety-related butterfly valve on a common SWS discharge header, causing the utility to decrease power. At Nine Mile Point, the main circulation water suction is located below the level of the service water pump suction. A situation there caused the intake gates to be closed and water was drawn down to a level where the service water pump suction was almost lost.

3. INSPECTION GUIDANCE ASSISTANCE

The insights gained from PRA and operational experiences discussed in the previous sections were used to identify aspects of SWS design, operational conditions, and environmental conditions that can contribute significantly to the risk of core damage at a plant.

When appropriate, each of the inspection items listed below has been associated with the characteristics of plant design or the environmental conditions that are likely to make the issue risk significant. Although a majority of the listed inspection items have some degree of applicability to all plants, the goal of this report is to focus inspection efforts at each plant on the items that are most likely to be risk significant at that plant. Therefore, some of the items are indicated only for plants with specific characteristics because those items are much less likely to be important to risk at plants without those characteristics. However, when planning an inspection for a specific plant, it is wise to be alert to the potential for risk significance of any of the listed items because of special circumstances beyond the consideration of this report. The inspection items listed below are arranged so those with the broadest applicability appear first.

All listed items have been deemed to have potential risk significance. The extent of this risk significance is dependent on many specific plant features and environmental characteristics. As a consequence, what may prove to be a very risk significant item at one plant may be inconsequential at another plant. Therefore, it is impossible to generically rank these inspection items according to importance.

3.1 Common-Cause Failure Potential (applicable to all plants)

Risk studies indicate that the largest contribution to risk comes from common-cause failure. Many of the subsequent inspection items that are identified as potentially risk significant are important because of the potential for common-cause failure of key components in the system.

Of particular importance is common-cause failure of pumps. Common-cause failure of HXs is also significant. Control systems that automatically initiate a realignment of the system under certain accident conditions can be a source of common-cause failure. Improper corrective or preventive maintenance of equipment and improper valve alignments are example of human errors that can also contribute to common-cause failure.

When reviewing past history and maintenance records, and when considering the remaining inspection items, potential common-cause failures should be scrutinized.

3.2 System Unavailabilities (applicable to all plants)

Individual independent failure of specific components typically does not contribute significantly to the failure risk for systems like the SWS. However, plants that are experiencing a high unavailability of individual SWS trains become more susceptible to an independent failure in the opposite train of ESF equipment or support equipment.

An assessment of the unavailability of the SWS trains should be performed with respect to equipment failures, repair time, down-time for surveillance and testing, and outage time for preventive maintenance. The assessment should be performed with regard to how individual pieces of equipment may affect the unavailability of a train.

3.3 Intake Clogging or Blocking (applicable to all plants)

Many plants have experienced the clogging or blocking (e.g., shutting of intake gates) of their traveling screens and intakes because of debris, fish, and other marine life (e.g., jelly fish, seaweed, grass, leaves). As the intakes become clogged or blocked, the condenser circulating water (CCW) can draw down the water level, reducing the net-positive suction head (NPSH) for the service water pumps. Depending on the location of the CCW pump suction compared to the SWS pump suction, it is possible to uncover the service water pump suction first. This may cause a loss of service water pump suction. If the CCW pump suction becomes uncovered before the service water, the CCW system will cease to draw down the water level and the service water pumps may still have an adequate water level, depending on the pump's NPSH requirements. Also, the clogging or blocking of screens and intake structures can cause a high enough differential pressure to create structural damage (screen may collapse, gates may jam, etc.), allowing debris to enter the pump intake.

Assessment of the plant's experience should be performed with respect to whether any clogging of intakes has been experienced. An evaluation of the location of the SWS intakes with respect to the CCW intakes should be performed to determine which would lose suction first in case of a draw down situation. An evaluation of NPSH requirements for the SWS pumps should be done. An evaluation of the screens to resist a large differential pressure (caused by clogging) should be performed. An evaluation of controls and logic for the intake gates (if present) should be performed as well as a review of any operational problems with them.

3.4 Debris Intake Potential (applicable to all plants)

Some plants may have inadequate screening or the screening is of inadequate strength to prevent course debris from entering the SWS. Experience has shown that debris has been the cause of several problems in the SWS, in particular, the fouling and damage of SWS pumps. In plants which use rivers for SWS intake, floods may cause a significant localized increase in debris. The likelihood of common-cause failure of SWS pumps because of debris intake in these plants may be a potential problem. Plants located in such areas are usually designed to prevent debris intake. Any history of debris ingress in the SWS would indicate potentially inadequate intake protection.

Assessment of the plant's experience should be performed with respect to whether the SWS has had any problems with debris. An evaluation of the intake structure design with respect to its ability to resist debris intake should be considered. The likelihood of the intake environment to produce a significant debris ingress problem should be assessed.

3.5 Silting (applicable to all plants)

Experience has shown that HXs have been coated with silt, reducing the heat transfer capability, the flow rate, or the flow balance. Areas within the system that experience low flow rates or are stagnant are particularly vulnerable.

Water with high levels of suspended solids can also be abrasive, possibly causing accelerated erosion. Areas within the system where flow rates are the fastest or where flow is turned (e.g., pipe elbows) are particularly vulnerable to this type of erosion.

These silting or erosion conditions continuously degrade the system and may be detected prior to system failure. Systems that have undetected degradation may work adequately in normal conditions, but may be incapable of meeting heat removal or flow requirements in accident conditions, thereby creating a risk significant condition. Also, silt accumulations can prevent valves from closing or opening adequately.

When reviewing maintenance records and component history information, determine whether silting conditions exist and whether the licensee has taken appropriate actions to prevent recurring problems and to ensure adequate heat transfer capability.

3.6 Common Flow Path (applicable to all plants)

Risk studies have indicated that common flow paths for redundant equipment can be a source of significant risk. Experience has shown that flow paths may be blocked or subject to other failures.

An assessment of the design should be completed to determine if common flow paths exist for redundant equipment. For common flow paths that contain valves, flow restrictors, or other mechanized devices (such as strainers), the reliability of those components should be assessed. This equipment should also be evaluated with regard to its susceptibility to plugging. Piping in common flow paths should be assessed for its integrity (wall thinning, support, etc.) and its ability to resist plugging. Redundant trains of SWS often share a common discharge pipe that may contain valves or other components vulnerable to plugging type failures.

3.7 Single Failure Susceptibility (applicable to all plants)

Experience has indicated that some plants may be susceptible to single failure problems. These problems tend to be more prevalent in older plant designs, but newer plants have also experienced this problem. Also, designs where the SWS is used as a backup water source for another system (e.g., component cooling water or auxiliary feedwater) may have a single failure potential that has been overlooked.

An assessment of the SWS in all possible mode or lineup configurations should be performed to determine if single failure potentials exist.

3.8 Net-Positive Suction Head of SWS Pumps (applicable to all plants)

Experience has shown that the NPSH requirements of the SWS pumps are not met in some cases. This can create a reduced or no-flow condition, possibly causing increased impeller wear. Plants that operate near the limit of NPSH requirements could experience a sudden loss of all flow, creating a risk significant scenario.

An assessment of NPSH requirements should be performed for the SWS pumps. An evaluation of maintenance for the SWS pumps should be performed to determine if damage from cavitation has occurred. Intake level and temperature should be evaluated against pumping conditions in various possible lineups for the SWS (especially for the lineup of accident modes of operation).

3.9 Modification to SWS (applicable to all plants, but in particular, those that are pre-Three Mile Island or have had a large number of changes to the SWS)

Experience has shown that a reduction in SWS capability is possible after modifying the SWS system. In some older plants, the design requirements for the SWS may not have been adequately defined. Newer plants may have made modifications that cause the SWS to not meet design requirements.

Safety evaluations (10 CFR50.59s) performed on the SWS and associated systems should be evaluated. An assessment of how modifications may have altered conformance to design requirements should be performed. An assessment of whether temperature, pressure, or flow conditions have been affected by modifications should be performed. An assessment of potential equipment actuation should be made if control systems have been modified. Temporary modifications should also be assessed concerning the above areas. A review of postmodification testing should be performed.

3.10 Corrosion (applicable to all plants, but in particular, those that operate in salt water or brackish water environments)

Experience has indicated that plants that operate in environments with a high level of dissolved salts have a greater susceptibility to corrosion. Plants that have stainless steel or other highly corrosion resistant materials are less susceptible to corrosion. Corrosion can prevent proper valve operation, cause leaks, or interfere with flow and heat transfer. This is a slowly degrading phenomenon that can be detected prior to system failure. However, a degraded system may operate while in a normal mode, then fail when it is shifted to an emergency mode. Stagnant areas within the system are more vulnerable to corrosion. Situations where the system contains dissimilar metals (e.g., copper and steel) can create a potential for galvanic corrosion.

An assessment should be performed for an indication of corrosion problems. Also, look for noncode repairs, the use of dissimilar metals, and designs that can create stagnant areas. If dissimilar metals are used, check to see if they are adequately isolated from one another (electrically) or if they are protected by other methods such as sacrificial anodes. Root cause evaluation of failures should be evaluated. Standby systems and valves that are operated only in emergency conditions may be particularly susceptible to corrosion.

3.11 Cavitating Flow in the Pipe (applicable to plants with flow restrictors or throttled flow, especially with butterfly or gate valves)

Plants that have systems which use flow restriction devices (such as orifices) or butterfly and gate valves in throttled positions may have experienced cavitation. Such cavitation could erode pipes or valves. If the system must reposition valves to a closed position, eroded pipes could rupture or eroded valve disks may not be able to completely shut off flow, possibly causing system degradation or possibly complete system failure.

An assessment should be performed to evaluate the condition of valve disks that throttle flow. An assessment of piping conditions downstream of throttled flow or flow restrictors should be done.

3.12 SWS Serves as a Backup Water Supply to Another System (applicable to plants with this design feature)

Experience has shown that when the SWS is a backup water supply for another system (e.g., supplies water to the component cooling water or the auxiliary feedwater), complex system interactions and single failure vulnerabilities may be present. In some extreme cases, the SWS pumps may be subject to run-out conditions and may not be able to supply adequate flow to crucial heat loads when the SWS flow is required by other systems. In such cases, the SWS system flows become very low and pressures are low. Heat exchanger conditions in accident situations can cause the SWS water to boil, further reducing the flow. Likely candidates for situations such as these include HXs or heat loads that are at high elevations relative to the SWS pumps, at remote locations with respect to the SWS pumps, or are high flow resistant loads (e.g., containment coolers located high in containment).

Configuration of the SWS when providing flow to other systems should be evaluated with respect to the effects on pump operation and flow balances. An assessment of the highest piping elevation and highest flow resistant loads should be performed to determine if conditions can exist that may cause local coolant boiling. An evaluation of the possible SWS interactions should be performed to determine if the worst potential failure situation has been identified and if mitigation or system recovery is possible.

3.13 Microbiologically Induced Corrosion (applicable to plants that do not have treated water)

Problems caused by microbiologically induced corrosion (MIC) are similar to corrosion problems. Fresh water plants and areas with stagnant water appear to have a higher susceptibility to MIC, but the problem appears to be widespread.

An assessment should be performed for an indication of MIC problems. Look for situations that can create stagnant areas within the system. Root cause evaluation of failures should be evaluated. Standby systems or valves that are operated only in emergency conditions may be particularly susceptible to MIC.

3.14 Biological Growth in Treated SWS (applicable to plants that have treated water)

Experience has shown that chemical treatment can control biological growth problems like mussels or clams. However, there have been instances where the system has been treated yet biological growth has not been controlled. This was determined to be caused by improper location of treatment points or the use of unreliable or inadequate treatment methods.

Assessments of the system in combination with the treatment points should be performed to determine if areas exist within the system that may not receive adequate treatment. An assessment of the treatment system reliability should be performed. Assessments of maintenance records should be performed to determine if biological growth problems have occurred at the plant after the water treatment system was operating.

3.15 Biological Growth in Untreated SWS (applicable to plants that do not have treated water)

Experience has shown that a variety of biological growth such as mussels or clams may occur within the SWS at various plants. This biofouling has created problems by reducing flow or heat transfer capability. Experience has also shown that species have migrated or been introduced to areas that have previously not had problems.

Assessments of maintenance records should be performed to determine if biological growth problems have occurred at the plant. An evaluation as to whether the SWS water supply is known to support fouling species of clams and mussels should be performed. System flow and heat transfer coefficients for HXs should be checked. If records indicate that no previous problem with biofouling exists, check to ensure that the licensee has a program to detect if problem species have moved into the area.

3.16 Pipe Liner Failure (applicable to plants with lined pipes)

Events have occurred where SWS pipe lining (e.g., epoxy or coal tar) has become detached from the pipe, leading to blocking or plugging of HXs tubes. The pipe lining may become detached from the pipe through several different mechanisms, including peeling because of water flow, corrosion, thermal cycling, and material degradation leading to delamination.

Assessments of plugging signs (such as high differential pressures across HXs) that may be caused by pipe lining problems should be performed. Where possible, visual examination of the pipe lining condition should be performed.

3.17 Motor and Pump Horsepower Match [applicable to older plants (pre-Three Mile Island)]

Scenarios can exist where motors are operating at the limit of their design. During an accident, if a sudden increase in demand is placed upon the SWS pump motors, a simultaneous failure of several motors may occur. This failure may be more likely for undervoltage conditions because of the potential of an overcurrent situation. Experience indicates that older plants may be more susceptible to this type of problem because the design philosophy of older plants was to closely match motor horsepower with the pump requirements. Newer plants tend to use motors of higher horsepower than the pump requires, giving a greater safety margin. Also, older motors may suffer from degraded insulation because of aging. This aging may be accelerated if the motor is operating close to its design limits or the system has experienced severe undervoltage situations.

Assessment of SWS motor horsepower ratings versus the pump requirements should be performed. The plant's historical experience with undervoltage conditions and the plant's tendency to experience undervoltage conditions should be assessed.

3.18 SWS Design Inadequate to Meet Operational Demands [applicable to older plants (pre-Three Mile Island)]

Experience has shown that some older plants suffer from inadequate flow capacity or heat removal capability during accident conditions. Also, some designs may not meet seismic or separation requirements. Some of the SWS components in older plants were never rigorously tested to validate their ability to meet accident conditions during worst-case scenarios. Also, the design requirements for older plants may be inadequately or poorly defined. Startup testing at older plants did not require flow testing of individual SWS loads.

Review preoperational test records in conjunction with the design basis for the SWS and directly associated systems. Compare this review with current design requirements. Identify any system configurations or design margins that deserve further testing.

3.19 Flooding (applicable to plants with SWSs that are capable of gravity or siphon flow)

The SWS can be a significant source of internal flooding. Even though pumped flow may represent a significant flooding hazard, the more risk significant flooding scenarios tend to involve gravity or siphon flow. Potential for affecting both trains of a safety related system with a single flood source is most significant.

Assess the plants ability to isolate flow paths, including the condition and reliability of key valves that would be used to isolate the flow paths. Assess the condition, reliability, adequacy, and capacity to detect and diagnose flooding. Assess the design, condition, and capability of antisiphon devices such as check valves.

3.20 Minimal Redundancy in Pumps (applicable to plants which have only one pump per train or one pump per train plus a shared pump)

A high pump failure rate or frequent maintenance outages can cause risk significant SWS train unavailabilities. Therefore, it is important to review the pump-outage contribution to train unavailability for systems that have minimal pump redundancy.

Cross-connection capability between trains is important because it provides the ability to recover cooling capability from another train. Cross-connection capability of the SWS to another unit is very important for systems that have only one pump per train. The reliability of the crossties should be assessed, with emphasis placed on the adequacy of recovery procedures and valve surveillance testing.

3.21 Crossties Between Trains (applicable to plants with crosstie capability between trains in a single unit and/or with trains in another unit)

Crossties can contribute to risk by providing a link so that failures in one train may propagate to the other train. For systems with a normally open crosstie, isolation is usually required upon safety system actuation.

The reliability of the isolation function should be assessed. Common mode failure potential for crosstied systems or trains should be assessed. If the crosstie is normally isolated (or is in a stagnant line), it is important to assess the potential for accelerated corrosion leading to pipe failure or the accumulation of fouling material that could be swept into the operable train when the crosstie is utilized. Therefore, specific reviews of isolated crosstie connections should be performed.

3.22 Air Operated Valves and Solenoid Operated Valves

(applicable to plants with air operated valves (AOVs) and solenoid operated valves (SOVs) in the SWS)

Experience has shown that systems with AOVs have had problems with valves failing to shift to a fail safe position. The AOVs (with their associated SOVs) have failed to shift because the SOVs have become mechanically stuck. Often times the valves will be stroked or manipulated, thereby freeing them. There have been many instances of stuck valves being treated as operable once they have been loosened by mechanical agitations, leaving the root cause to remain undetermined and uncorrected. Such valves frequently become stuck again within a short period of time. This potential for valve malfunction represents a potential common mode failure.

An assessment should be made to determine if problems of the type described above exist. An evaluation of the root cause determination and corrective action should be performed to determine if the utility has adequately addressed such problems.

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11. ABSTRACT *(200 words or less)*

This risk-based inspection guide is intended to supplement U.S. Nuclear Regulatory Commission (NRC) Temporary Instruction 2515/115, "Service Water System Operational Performance Inspection (SWSOPI)." The purpose of this guide is to assist NRC inspection team leaders and team members to prioritize inspection items and refine inspection plans so their inspections will address those elements that dominate the risk associated with the service water system. This generic document presents risk insights obtained from probabilistic risk assessments and historical operating experience. Because it is intended to assist inspections at all commercial U.S. power reactors (which have wide variations in service water system designs), some items may not be applicable to every plant. Where possible, the risk significance of the potential inspection items has been related to particular characteristics of plant design or environmental conditions so that inspectors can determine which items may be applicable to a specific plant.

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